

Creation Matters

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Fascinating New Insights into the Design of Bacterial Flagella

by David Thomas

David (a pen name) is an undergraduate student who is currently studying biological sciences focusing on cell biology and genetics.

Many readers of *Creation Matters* will be familiar with bacterial flagellar motors being used as an example of design in nature. The bacterial flagellum (figure 1) was first used as an example of irreducible complexity by Michael Behe in his 1996 book *Darwin's Black Box* and has since become an icon of the Intelligent Design movement. In recent years, scientific knowledge about these fascinating molecular machines has exploded, and yet, almost all of these recent discoveries have not been discussed by biblical creationists or intelligent design advocates. I have spent the last year and a half researching these new discoveries and am currently working on a comprehensive review. Here, I'll give you a brief overview of some of the most important and fascinating discoveries and what they mean for the creation/evolution debate.

Many of these discoveries have come about thanks to a recent "resolution revolution" in a technology called cryogenic electron tomography, or cryo-ET for short. This revolution has allowed scientists to image proteins and molecular machines at, or near, atomic resolution. This has allowed scientists to see the design features of molecular machines, including bacterial flagella, in unprec-

edented detail. The proteins of molecular machines no longer appear as hazy blobs but as elegantly and intricately designed components.

Potentially, the most surprising discovery in the field due to cryo-ET is that the bacterial flagellar motor is not actually a single motor but is instead a rotary machine that is powered by multiple smaller

rotary motors (figure 2). These smaller motors form small, powered gears which are powered by an electric voltage across the inner membrane of bacterial cells. These powered gears surround and drive the rotation of a large central gear. In mechanical terms, this is a "two-cog-wheel gear system". The rotation of the central gear in turn results in the rotation

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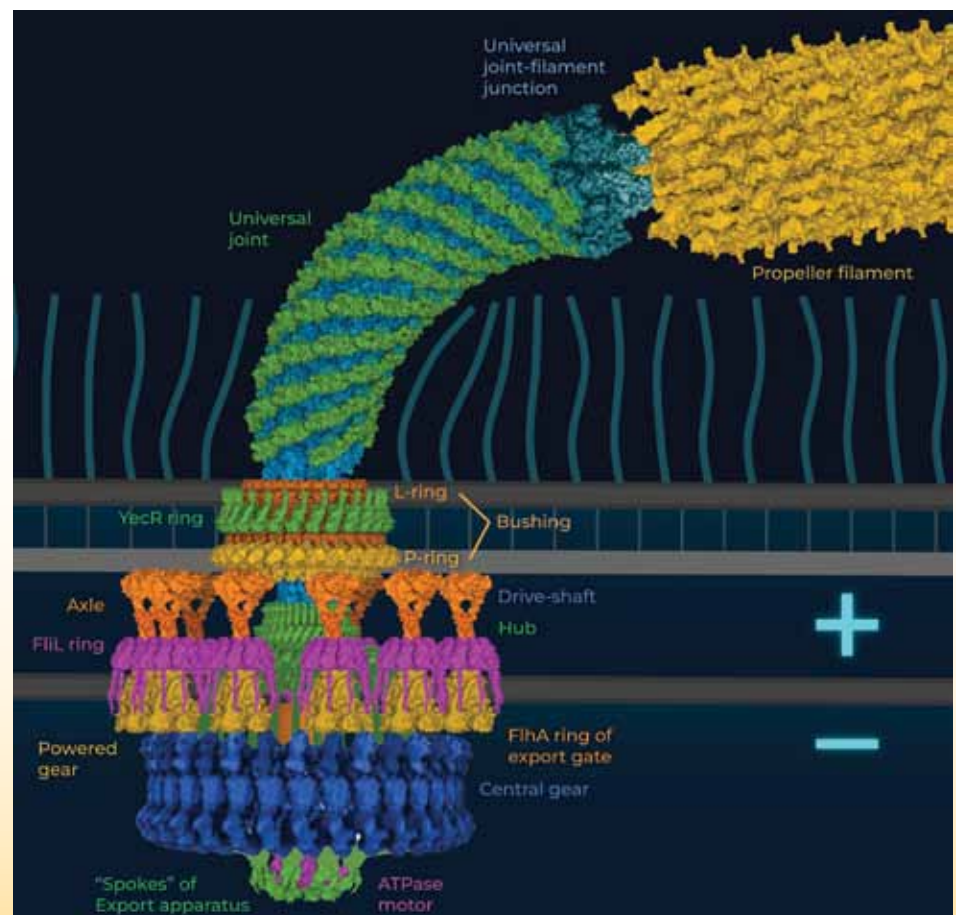


Figure 1: Illustration of the flagellar motor in *E. coli*, based on the current scientific data and protein structure predictions by the AI program AlphaFold. Illustration by D. Thomas.

Math Matters

Fireflies Flashing in Unison

by Don DeYoung, PhD

Bioluminescence is the production of light by organisms from internal chemical reactions. Examples are found in beetles, fungi, jellyfish, lantern fish, squid and glow-worms. Fireflies, popularly called lightning bugs, are of special interest. There are roughly 2200 species of these beetles scattered around the world.

Certain firefly species, including those in Appalachia, display a remarkable behavior. Swarms tend to synchronize their flashes as if an entire string of Christmas lights was flickering on and off. Earlier it was suggested that this coordinated behavior was an illusion, perhaps resulting from the viewer's involuntary blinking; however, close observations do show unified flashing.

Firefly signals help males and females recognize and find each other. The males typically flash in the air while stationary females respond from below. Initially it was thought that the insects have some type of biological metronome which controls the frequency of their light pulse. When unison flashing occurs in a swarm, the similarity then would be to a group of mechanical metronomes ticking together in resonance as coupled oscillators.

The internal metronome idea is now challenged by observations (Sokol, 2022). Individual fireflies display no apparent, intrinsic rhythm. When an individual does flash, however, this appears to trigger a similar response in nearby fireflies. The near-simultaneous flash occurs only when the number exceeds about 15 insects. And rather than flashing exactly together, closely-matched pulses move through the swarm at about one-half meter per second. That is, the fireflies respond to the lights of near neighbors in a cascading wave of coordinated flashes. This behavior is similar to the dynamic motion of flocks of birds and schools of fish.

An 8-second exposure of fireflies in Georgia.

Photo by Jud McCranie, Creative Commons.
https://en.wikipedia.org/wiki/Firefly#/media/File:Fireflies,_Georgia,_US.jpg

The question remains, why do firefly swarms display synchronism in their light show? The coordinated light display would appear to confuse the individual firefly courting process. In addition, why do certain fireflies often emit a light pulse which is exactly out of phase with the majority, flashing on and off while the majority flash off and on? The referenced article suggests *how* the group process works but not the *why*.

These small insects show baffling complexity in their group behavior. Flashing fireflies are an attractive creation mystery on summer evenings.

Sokol, J. (2022, September 20). How do fireflies flash in sync? Studies suggest a new answer. *Quanta Magazine*. Retrieved September 26, 2022, from <https://www.quantamagazine.org/tag/insects/> 

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of the propeller filament which propels the cell forward. Charged residues on the tips of the gear teeth allow the rotation of the small, powered gears to drive the rotation of the large central gear.

The discovery that flagellar motors are driven by even smaller motors has led to the discovery of how flagellar motors probably change rotation direction. It has long been known that flagellar motors can rotate both clockwise (CW) and counter-clockwise (CCW), when viewed from outside the cell, but it was not known how they change rotation direction. It turns out they use a very clever mechanical mechanism. Thanks to cryo-ET, we can see that flagellar motors change rotation direction by changing the diameter of the central gear (figure 3). The powered gears are assumed to always rotate CW. When the central gear contacts the inner side of the powered gears it rotates CCW. When the central gear expands to increase its diameter it engages with the outer side of the powered gears and so rotates CW. In mechanical terms, the central gear changes from an “external gear” to an “internal gear.”

It has also been discovered that flagellar motors have other gear-change mechanisms as well. Flagellar motors can automatically modify the number of powered gears engaged with the central gear to adjust the torque produced by the motor. When the motor needs to produce more torque, such as when swimming through thicker fluid, more powered gears are engaged. When the motor does not need to produce as much torque, powered gears disengage to conserve energy.

There are also different types of powered gears which use different types of fuel. By regulating the ratio of different types of power gears engaged with the central gear, some flagellar motors can automatically adjust the ratio of different fuel types used depending on fuel availability.

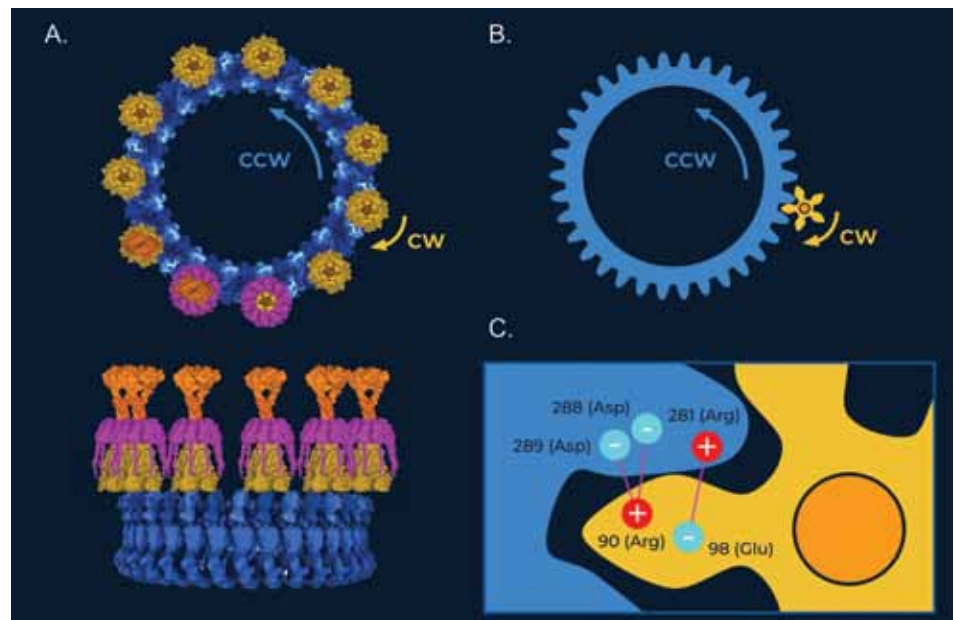


Figure 2: The gearbox of the flagellar motor of *E. coli* in forward gear. Illustration by D. Thomas.

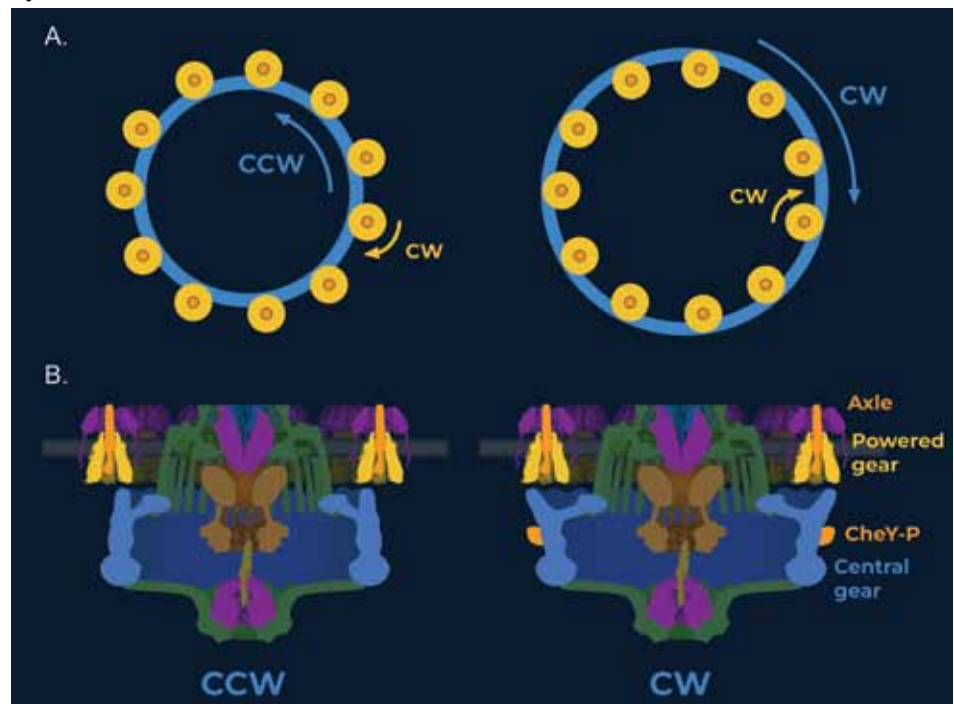


Figure 3: The flagellar gear box, viewed from outside the cell, showing the central gear (C-ring, blue), powered gears (MotA ring, yellow), and powered gear axle (MotB dimer, orange). The central gear is rotating counter-clockwise (CCW) on the left and clockwise (CW) on the right. The powered gears always rotate CW.

Thus, the number and type of powered gears engaged with each central gear are continually fine-tuned to match the requirements of the motor and maintain optimal performance.

One of the other fascinating discoveries is the huge diversity of flagellar motor

designs across the bacterial kingdom (figure 4). It is no longer accurate to talk about “the flagellar motor” because there are so many different designs. All flagellar motors discovered so far contain the same core set of parts but some of these parts can have significantly different de-

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signs between different species depending on the needs of each species. Beyond this, the flagellar motors in many species also contain multiple additional parts that are needed for their specific environments. Many of these additional parts are involved in stabilizing the powered gears during ultra-high-speed rotation; other parts function as brakes or clutches. Still, many other components have functions that have not yet been discovered. The more we know about flagellar motors the more we discover how astonishingly similar they are to human-designed motors. Flagellar motors have many parts which perform similar functions to parts in human-designed motors including gears, rotors, axles, driveshafts, bushings, ball bearing-like bearings, brakes, clutches, structural scaffolds, hinges, universal joints, other joint types, adaptor rings, sockets, switches, stators, capacitors, channels for fuel to flow through, mechanical sensors and components which respond to signals from the navigation system and other control systems.

There is also a huge diversity in the number of motors per cell, where they are located in the cell, how they are arranged, the design of the flagellar propellers, whether the propellers are located inside or outside the cell, whether the propellers are encased in a sheath or not, the design of the sheath, what the sheath is made of, and much more. More details will be described in my upcoming technical review.

What astonishes me far more than these features above is the programming associated with bacterial flagella. Multiple different ultra-advanced biological computer programs are required to control the motors to steer the cells through their environment, to regulate changes in motor function needed for changes in lifestyle, and to manage the timing and logistics of the factory-like assembly of bacterial flagella and the hardware that

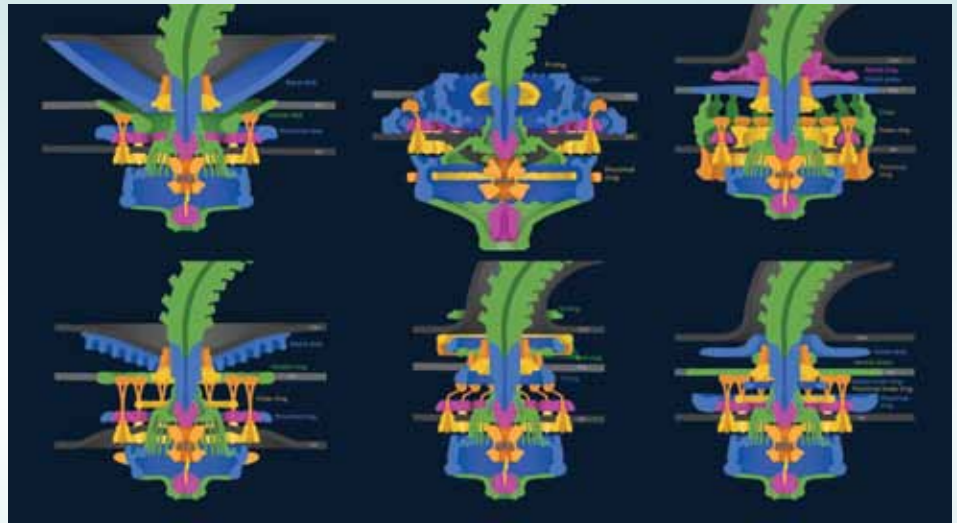


Figure 4: Cross sections through six of the many different flagellar motor designs.

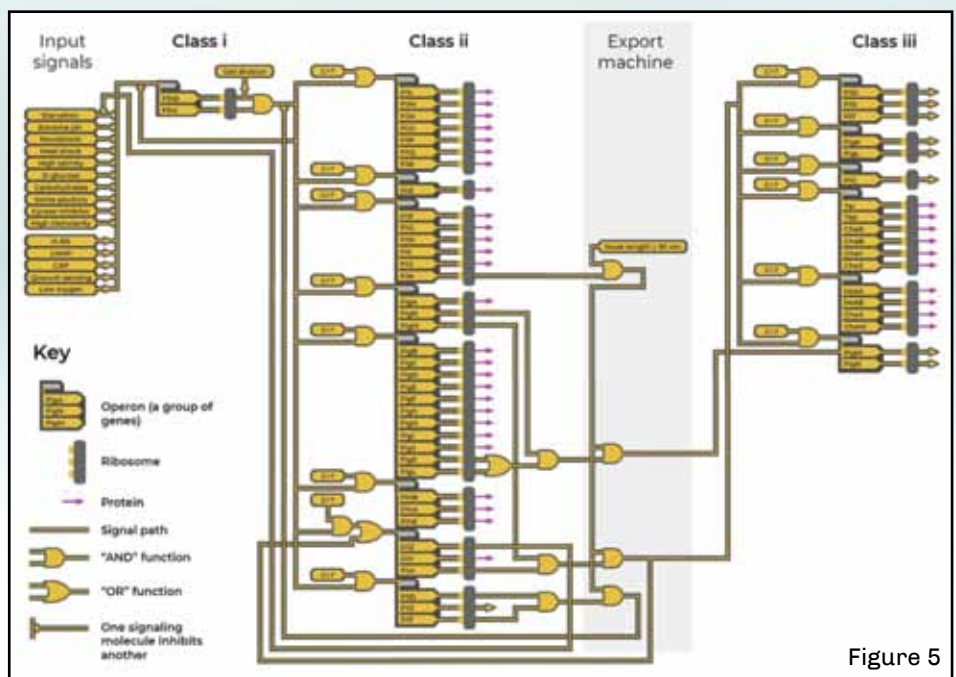


Figure 5

Figure 5: A simplified diagram of the genetic program that controls the timing and logistics of the construction of the flagella in *E. coli*.

the navigation system runs on (figure 5). These programs are so advanced that humans have gotten inspiration from them to improve our own computer programs. This is a further indication that a creation/design-based approach to science is fruitful.

One thing that has surprised me as I've studied these machines is the sheer number of design constraints that the motors must satisfy to work. In line with this, I have been amazed at the sheer number of design features bacterial flagella have to

meet these design constraints. Designing an ultra-efficient, ultra-fast rotary motor at this scale is a hugely complex engineering challenge. Yet, bacteria have these machines.

Conclusion

When Darwin published *On the Origin of Species*, the cell was viewed as a lump of protoplasm. At that time, it was easy to imagine cells arising from natural processes. However, we now know that

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Historical Narratives and the Fossil Record

by Jean K. Lightner, DVM, MS

Q: How can anyone claim there are huge gaps in the fossil record given the abundance of intermediate fossils?

A: This question comes from my interaction in an evolutionary biology class. It made it clear to me how anyone can get so caught up in their own paradigm, they miss overall patterns of evidence. Though I unswervingly believe the history presented in the Bible is true, as a scientist I need to be able to see how evidence is interpreted in more than one paradigm. I need to understand how evolutionists think, as it helps in conversations related to scientific evidence. Certainly, this is healthy for any scientist regardless of their preferred paradigm for interpretation.

The evolutionary expectations

Evolutionists interpret fossil evidence within the context of universal common ancestry. Therefore, all life is believed to be related by common descent, and that drives what hypotheses are considered and how evidence is interpreted. Superficially, this paradigm seems to make very good sense of the evidence. Lower in the fossil record are more marine creatures, and “simpler” life forms. So, it seems logical to believe life evolved in the ocean and eventually moved onto land. There have been times where evolutionists have looked for intermediates in specific layers that, based on their historical narrative, they were predicted to exist. *Tiktaalik* is a fossil species found based on this strategy and is claimed to be an intermediate on the path to terrestrial, four-footed

animals.

The creationist expectations

In contrast, creationists use a different historical narrative, the one found in the Bible. If the Bible is true, then its history gives us crucial insight to avoid many pitfalls, both scientifically and spiritually, that we would otherwise naturally fall into. One of the expectations of creationists is that life naturally groups into kinds. This is based on Genesis 1, where plants and animals are created “according to their kinds.”

Creationists have used a variety of anatomic and physiologic characteristics, as well as comparisons of sequence data from DNA and proteins, to identify distinct groupings of organisms. When it comes to the fossil record, currently statistical tools are used, and groupings have been found. As with all tools used by scientists, statistical baraminology tools have their limitations. Nevertheless, they remain important for creationists to use and continue to develop as we seek multiple lines of evidence to identify created kinds (Wood, 2021).

Where are gaps expected?

The evolutionary narrative doesn’t predict any gaps. However, evolutionists do recognize that special conditions are needed for fossilization, and some organisms may be less well represented in the fossil record because they do not get fossilized as readily. So, some gaps could be apparent for these secondary reasons.

In contrast, creationists predict that discontinuity (gaps) should be found in many places. Previous work suggests that most eukaryotic baramins (created kinds) are represented by families, sub-orders, or orders today (Wasmann 1910, pp 291-292; Lightner 2012; 2013; humans excepted, since evolutionists have now placed us in the same family as great apes despite some profound differences, e.g., see Tomkins, 2016 and Lightner and Cserhati, 2019). Thus, most notable gaps should be above the level of the family, and different orders should typically have morphological (and genetic) gaps between them.

The largest gaps evidenced in the fossil record are predominantly at the higher taxonomic levels, in the place the creation model would predict. This is particularly problematic for evolutionists because the vast differences in form should have been crossed by the most intermediates. So, theoretically, most of the intermediates found in the fossil record should be found between different kingdoms and phyla, but they are not. Therefore, the Cambrian explosion (sudden appearance of most extant phyla in the Cambrian layer) is a profound problem to the idea of universal common ancestry.

Creationists expect continuity, or the opposite of huge gaps, to still be observable within created kinds. Thus, both interpretive paradigms have no trouble explaining intermediates at lower taxonomic levels. This continuity can be found in various orders or below for most familiar taxa, such as insects, birds, and mammals.

Closing the gaps

In the discussion of the fossil record in the evolutionary biology class that I was privileged to participate in, there were some interesting patterns. First, the problem of gaps between phyla was pretty much ignored and a red herring (i.e., ad-

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vanced vertebrates were not represented) was put in its place. Second, *Tiktaalik* was presented as an intermediate in the assumed fish to tetrapod transition (which would cross classes, a rank above the order). It was promoted as one example of many where the transition was well worked out and understood.

I had encountered this type of promotion of the fossil record in my undergraduate days, only to find out that in graduate level classes the problems with these supposed “wonderful examples” are more honestly presented. So, in keeping with the admonition in 1 Thessalonians 5:21 to test everything and hold on to the good, I did some internet searching, using readily available sources such as Wikipedia and PubMed.

Tiktaalik is a lobe-finned fish, as is the coelacanth (*Latimeria* spp). *Tiktaalik* is found in Upper Devonian strata. While it has some features that are more “tetrapod-like” than other fish, its classification as a fish is not seriously disputed. In the class discussion the evidence for tetrapod tracks earlier in the Devonian was dismissed as controversial. However, I was easily able to find a PubMed article that was not so dismissive (Lennie et al., 2021). What follows is a quote from the abstract:

Evidence for terrestriality in early tetrapods is fundamentally contradictory. Fossil trackways attributed to early terrestrial tetrapods long predate the first body fossils from the Late Devonian. However, the Devonian body fossils demonstrate an obligatorily aquatic lifestyle. Complicating our understanding of the transition from water to land is a pronounced gap in the fossil record between the aquatic Devonian taxa and presumably terrestrial tetrapods

from the later Early Carboniferous. Recent work suggests that an obligatorily aquatic habit persists much higher in the tetrapod tree than previously recognized.

I did a quick read through of the Lennie et al. (2021) article and found it fascinating. It used evidence from what we know (bone responds in particular ways to use) and looked for evidence of limb use in late Devonian to mid-Carboniferous fossils. This was of special interest to me because I had been in dialog with a student about how bone responds to use in a discussion as to whether wisdom teeth are vestigial (from genetic loss), or underdeveloped due to lack of use. While Lennie et al. (2021) interpret the evidence within the evolutionary paradigm, they are using techniques that can help us better understand these extinct organisms. I encourage any interested in vertebrates and/or paleontology to read the original article further.

Challenge for creationists

While gaps between higher taxa are a conundrum for the evolutionary view, as creationists we deal with huge gaps in our own understanding of the fossil record. What do we know so far? We can see a tremendous amount of diversity in the past compared to what we see today. We can see that some manmade taxonomic categories (e.g., reptiles) are not as neat as we had believed. We see that fossils group, consistent with creationist expectations, even if some groups jar our previously held beliefs in some areas (e.g., what organisms have feathers; McLain et al., 2018)

Yet, how does the record in Genesis help us understand any of this? The flood would provide a means of forming lots of fossils. The order has loosely been explained as a succession of different communities being buried in sequence, but where are the testable hypotheses or evidence from catastrophes today

that corroborate this? Currently, there is no agreement on the flood/post-flood boundary. Why does it seem the low boundary would imply numerous kinds of creatures became extinct during the flood, that new kinds appeared afterward, and that some mammals evolved to become more complex (e.g., ruminants)? Why does a high flood boundary seem to imply that many vertebrates survived the flood outside the Ark, remaining on the same continent they were confined to before?

Attacking a worldview that we disagree with will not resolve the numerous challenges that the fossil record poses for the biblical creation worldview. It has taken well over a century for biology to recover from evolutionary ideas (e.g., all mutations are random with respect to fitness, natural selection always works for the good of the organism, adaptation can be explained by neo-Darwinian mechanisms, etc.). So, it is reasonable to expect that it will take considerable time to discover and sort out the patterns of evidence in the fossil record. While the small group of creation paleontologists is slowly growing, they still are a small fraction of the creation scientists compared to those working in biology.

So, I issue a challenge to myself and my fellow creationists today. May we humble ourselves before our Mighty Creator, recognizing how much we still do not know. May we implore our Creator, who gave us the record of Genesis, for more scientific laborers and divine wisdom to see how it all fits. May we pray for young scientists to study and see important patterns in the evidence that will enable us to gain a clear picture of geology and the fossil record in light of Scripture. There is no question that a proper understanding of geology and the fossils will give God glory. In the meantime, as we pursue that goal, we need to pray that Christian love and harmony would permeate our discussions where we necessarily have different viewpoints and conclusions. If

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cells are mind-blowingly complex with multiple integrated systems and pathways governed by numerous molecular machines. The sophistication of bacterial flagella has far exceeded our expectations and far surpasses the most advanced human nanotechnology.

Where there is a lack of data there is room for speculation. A few years ago, when there were many unknowns around flagellar motors, it was easy for evolutionists to suppose with a wave of the hand that they could have evolved by chance through the functional conversion of similar proteins from other molecular machines. However, thanks to the detailed knowledge we now have about these machines, we can show that the probability of even a single flagellar protein evolving by chance is virtually impossible — even if one waited multiple times longer than the evolutionary age

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we do not glorify God in our behavior towards each other as we seek to find answers, why would we expect our proud hearts to be able to recognize those answers when they are revealed?

I will be praying; how about you?

All of you, clothe yourselves with humility toward one another, because, “God opposes the proud but gives grace to the humble.”

1 Peter 5:5b NIV

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of life on earth. Evolutionists are thus “without excuse” for rejecting the evidence for a creator (Romans 1:20).

If the sophistication of our most advanced nanotechnology pales in comparison to the design of even part of these molecular machines, what does this tell us about the One who designed them? As God says in Isaiah 55:8 (ESV): “For as the heavens are higher than the earth, so are my ways higher than your ways and my thoughts than your thoughts.” The beautiful design of these motors clearly displays God’s Glory. Psalm 104:24 (ESV) says it well: “O LORD, how manifold are your works! In wisdom have you made them all; the earth is full of your creatures.”

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